

A List of Groups of Dwarf Galaxies in the Local Supercluster

D. I. Makarov^{1,*} and R. I. Uklein^{1,**}

¹*Special Astrophysical Observatory, Russian Academy of Sciences, Nizhnii Arkhyz, 369167 Russia*

We report a list of groups consisting of dwarf galaxies only. The sample contains 126 objects, mainly combined in pairs. The most populated group contains six dwarf galaxies. The majority of systems considered reside in the low-density regions and evolve unaffected by massive galaxies. The characteristic sizes and velocity dispersions of groups are 30 kpc and 11 km/s, respectively. They resemble the associations of dwarf galaxies, but are more compact. On the whole, groups and associations form a continuous sequence. Alike the associations, our groups possess high mass-to-luminosity ratios, what is indicative of a large amount of dark matter present in these systems.

1. INTRODUCTION

Contemporary mass surveys, such as 2dF [1], HIPASS [2], 6dF [3], ALFALFA [4] and SDSS [5] have substantially enriched our knowledge of redshifts in the near Universe. The number of measured velocities within the Local Supercluster has increased by a factor of three to four over the past decade. Owing to all-sky surveys, redshifts have become known not only for the giant, but also for a large number of dwarf galaxies.

In their recent series of papers, Makarov and Karachentsev [6–8] have studied the distribution and properties of multiple systems of galaxies on the scale of the Local Supercluster. In [6] a large number of pairs consisting exclusively of dwarf galaxies was brought to notice. Extremely metal-poor galaxies can be found among such systems, like, e.g., the well-known system

IZw 18 and the pair of galaxies HS 0822+3542a and SAO 0822+3545 [9]. Most of the multiple dwarf galaxies contain young stellar population, which is reflected in the color and morphology of these systems. Radio observations of such objects have shown that they contain large volumes of neutral hydrogen [10].

Tully et al. [11] used high-precision photometric distances to study the three-dimensional distribution of nearby galaxies on the 3 Mpc scale and identified systems of dwarf galaxies in the neighborhood of the Local Group. Such structures, which were called the associations of dwarf galaxies, have the mass-to-luminosity ratios in the 100–1000 M_{\odot}/L_{\odot} interval and contain large amounts of dark matter. The discovery of pairs of dwarf galaxies on the scale of the Local Supercluster is indicative of a wide occurrence of such systems in the Universe.

* Electronic address: din@sao.ru

** Electronic address: uklein@sao.ru

2. GROUPS IN THE LOCAL SUPERCLUSTER

This paper continues a series of papers by Makarov and Karachentsev aimed at the study of multiple systems on the scale of 40 Mpc [6–8]. These papers provide a detailed description of the technique of identification of groups and analysis of the sample obtained. Here we only briefly describe the necessary details of catalog creation. Radial velocities, magnitudes, morphological types, and other galaxy parameters were adopted from the HyperLEDA and NED databases. Both databases contain a large amount of false data, which appear due to the automatic procedures of data reduction. The most common types of pollution are: confusion of the coordinates and velocities of galaxies closely located in the sky; objects with false line-of-sight velocities obtained from the mass 2dF-type sky surveys; apparent magnitudes from the Sloan Digital Sky Survey (SDSS) survey refer to individual regions of extended galaxies. We corrected these and some other errors as far as possible. Visual control of galaxy parameters was a very important and most time-consuming stage when working with the catalogs of groups [6–8]. As a result, we obtained a sample of 10 914 galaxies with line-of-sight velocities in the reference frame of the Local Group $V_{LG} < 3500$ km/s located at the galactic latitudes of $|b| > 15^\circ$. A sample of such a depth comprises the entire Local Supercluster with all its neighborhoods.

The clustering algorithm for multiple systems [6–8] is based on the natural requirement that the total energy of the physical pair should be negative. At the first stage we computed the boundedness criteria for all galaxy pairs in the sample: the total energy of the system should satisfy the inequality $\Delta V^2 \Delta R < 2GM$ and the galaxies should reside inside the zero-velocity sphere $\pi H_0^2 \Delta R^3 < 8GM$, where ΔV and ΔR are the velocity difference and the difference of projected distances in a pair of galaxies, and M is their total mass. We combined the pairs selected by these criteria into groups and repeated the process while there was at least one pair meeting the above criteria. The algorithm uses only the information on the coordinates, redshifts, and magnitudes of objects. We determine the distances to galaxies using the Hubble law with $H_0 = 73$ km/s/Mpc. The masses were estimated by the near-infrared integrated Ks -band magnitudes of galaxies assuming that all galaxies have equal mass-to-luminosity ratios.

We adopt most of the photometric data from the 2MASS all-sky survey [12, 13]. In the absence of K -band estimates we converted the optical (B , V , R , I) and near-infrared (J , H) magnitudes into the K -band magnitudes, as described in the series of papers [6–8].

As a result of clustering, 5926 galaxies have been combined into 1082 systems consisting of two and more members. Makarov and Karachentsev [8] showed that the median velocity dispersions and harmonic radii of groups with

$n \geq 4$ members in the Local Supercluster are equal to $\sigma_V = 74$ km/s and 204 kpc, respectively; the mean crossing time is about 2.2 Gyr; the typical mass of a group is $M_p = 2.3 \times 10^{12} M_\odot$ and the K -band mass-to-luminosity ratio is $M/L = 22 M_\odot/L_\odot$.

3. GROUPS OF DWARF GALAXIES

Karachentsev and Makarov [6] pointed at the existence of an unexpectedly large number of pairs consisting of dwarf galaxies. Although such systems have been already known for a while, including the most famous of them—the pair of galaxies IZw 18 A and IZw 18 C [14], the groups of dwarf galaxies have until recently remained outside the focus of attention.

Figure 1 demonstrates the distribution of luminosities of the brightest and second brightest group members for the groups from [6]. The systems that have caught our attention are located to the right from the vertical line. We compiled a list of groups of dwarf galaxies based on the catalogs of groups in the Local Supercluster [6–8]. The sample of galaxies from these papers was slightly modified. We added new and updated the available line-of-sight velocities and magnitudes of galaxies using the published data. The changes made in the process of refinement and correction of the HyperLEDA data were taken into account. We also updated the data on groups of galaxies in the Local Supercluster using the original clustering algorithm. The

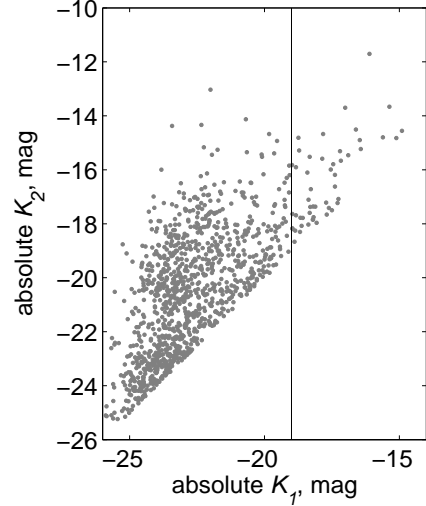


Figure 1. Dependence of the absolute magnitude of the second brightest member K_2 on the absolute magnitude of the brightest member K_1 . The groups of dwarf galaxies are located to the right from the solid line ($M_K > -19$ mag). This plot corresponds to the right-hand panel of Fig. 7 from [6].

list of dwarf galaxies now includes systems, in which the brightest galaxy has the K -band absolute magnitude fainter than $M_K = -19$ mag, while these groups are not the substructures of brighter formations. This allowed us to mainly select dwarf irregular galaxies with a small number of late-type galaxies (Sdm–Sm) among the brightest objects.

We cleaned the resulting sample from false systems. Such formations may appear in the regions with high negative peculiar velocities near the clusters of galaxies. The use of the Hubble law for determining the distances to them may result in a substantial underestimation of total luminosities of galaxies.

We visually searched for possible group members without known line-of-sight velocities

around the selected systems in the region of approximately $1^\circ \times 1^\circ$. The main criterion of visual selection was the morphological consistency between the candidates and known members and the agreement of their redshifts. We performed our search only within the SDSS coverage region. Our list also incorporated multiple dwarf systems, that we identified in the process of visual inspection of images within the verification of galaxy data reliability in the HyperLEDA database. This was not a systematic search and it affected only the galaxies that have caught our attention for some reason.

Note that a visual search for multiple dwarf systems on the SDSS images revealed more than 20 candidates, which subsequently failed to pass the isolation criteria. These close dwarf systems

proved to be subsystems located around bright galaxies or inside the more massive groups.

We present the list of groups of dwarf galaxies in Table 1. The columns of the table give: (1) the name of the group in the list; (2) the designation of the component based on the number of a given galaxy in the order of increasing right ascension; (3) the name of the galaxy according to common catalogs; (4) J2000 coordinates of the galaxy; (5) line-of-sight velocity V_{LG} with respect to the center of the Local Group in accordance with [15]; (6) apparent B -band magnitude, which was estimated from the SDSS g and r -band photometry (see Table 1 from [16]) or adopted from the HyperLEDA database [17]; (7) the absolute B -band magnitude; (8) the main disturber (MD) and index of isolation (II) of the group.

Table 1. The list of dwarf galaxy groups

Group		Galaxy name	R.A. Dec	V_{LG} , km/s	m_B , mag	M_B , mag	MD	II
(1)	(2)	(3)	J2000 (4)	(5)	(6)	(7)	(8)	(9)
J0130+02	A	UGC 1075	01 30 02.5 +02 51 09	2227 ± 6	16.60	-15.92	NGC 488	1.29
	B	LSBC F828-01	01 30 29.0 +02 49 55	2240 ± 10	17.00	-15.53		
J0310-41	A	LCRS B030900.1-415914	03 10 49.7 -41 47 57	1253 ± 74	16.03	-15.20	NGC 1399	1.75
	B	LCRS B030909.4-415056	03 10 59.2 -41 39 40	1186 ± 26				
J0453-61	A	ESO 119-016	04 51 29.2 -61 39 03	739 ± 10	14.89	-15.24	NGC 1796	1.19
	B	SGC 0454.2-6138	04 54 55.4 -61 33 53	745 ± 9	16.09	-14.05		
J0532-25	A	ESO 487-017	05 30 29.0 -24 52 35	1661 ± 13	16.24	-15.76	NGC 1964	5.79
	B	ESO 487-020	05 32 23.8 -25 13 55	1750 ± 74	16.14	-15.92		
	C	AM 0530-245	05 32 46.5 -24 55 33	1684 ± 74	16.67	-15.31		
J0700-04	A	HIZSS 003 A	07 00 28.2 -04 12 26	109 ± 11	18.00	-12.29	LG	5.89
	B	HIZSS 003 B	07 00 24.6 -04 13 13	143 ± 11				

Table 1. (Contd.)

Group		Galaxy name	R.A. Dec	V_{LG} , km/s	m_B , mag	M_B , mag	MD	II
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
J0714+44	A	UGC 3698	07 09 18.7 +44 22 48	465 ± 5	15.16	-14.35	M 81	22.90
	B	NGC 2337	07 10 13.6 +44 27 26	477 ± 5	13.10	-16.39		
	C	UGC 3817	07 22 44.5 +45 06 31	478 ± 2	15.96	-13.63		
J0723+36	A	SDSS J072313.46+362213.0	07 23 13.5 +36 22 13	967 ± 1	19.31	-11.54		
	B	SDSS J072301.42+362117.1	07 23 01.4 +36 21 17	914 ± 1	17.01	-13.72		
	C	SDSS J072320.56+362440.9	07 23 20.6 +36 24 41	935 ± 1	21.59	-9.19		
J0742+16	A	UGC 3974	07 41 55.4 +16 48 09	162 ± 5	13.62	-13.24	M 81	49.14
	B	CGCG 087-033	07 42 32.0 +16 33 40	168 ± 5	15.43	-11.49		
J0747+51	A	MCG +09-13-052	07 46 57.0 +51 17 47	510 ± 5	16.66	-12.85	NGC 2500	12.11
	B	KUG 0743+513	07 47 32.0 +51 11 29	503 ± 5	15.14	-14.32		
J0817+24	A	LCSB S1123P	08 17 15.9 +24 53 57	1832 ± 5	17.11	-15.17	IC 2267	8.42
	B	KUG 0814+251	08 17 21.0 +24 57 46	2076 ± 5 [†]	17.12	-15.43		
J0821-00	A	UGC 4358	08 21 26.0 -00 25 08	1606 ± 6	15.96	-15.94	UGC 4254	74.24
	B	6dF J0821428-002601	08 21 42.8 -00 26 01	1612 ± 74	16.48	-15.43		
J0825+35	A	HS 0822+3542a	08 25 55.5 +35 32 32	698 ± 3	16.57	-13.53	NGC 2683	43.55
	B	SAO 0822+3545	08 26 05.6 +35 35 26	712 ± 2	18.34	-11.80		
J0852+13	A	SDSS J085233.76+135028.4	08 52 33.8 +13 50 28	1360 ± 3	17.15	-14.34		
	B	SDSS J085240.94+135157.0	08 52 40.9 +13 51 57	1390 ± 22	19.56	-11.98		
J0859+39	A	UGC 4704	08 58 59.0 +39 12 40	581 ± 6	15.51	-14.12	NGC 2683	18.29
	B	SDSS J085947.03+392302.6	08 59 46.9 +39 23 06	573 ± 34	17.23	-12.37		
J0911+42	A	SDSS J091108.40+423922.1	09 11 08.4 +42 39 22	1498 ± 13	16.02	-15.61	NGC 2798	14.93
	B	SDSS J091110.62+423801.4	09 11 10.6 +42 38 01	\pm	18.81			
J0915+48	A	UGC 4868	09 14 51.8 +48 35 37	2822 ± 5	17.43	-15.58	NGC 2856	4.61
	B	UGC 4874	09 15 16.3 +48 40 03	2821 ± 5	17.60	-15.41		
	C	SDSS J091552.07+484119.5	09 15 52.1 +48 41 20	2809 ± 17	18.08	-14.94		
J0934+55	A	IZw 18 C	09 33 59.7 +55 14 45	821 ± 5	19.73	-10.66	NGC 2841	8.34
	B	IZw 18 A	09 34 02.0 +55 14 28	837 ± 4	16.48	-13.95		
J0950+31	A	UGC 5272b	09 50 19.5 +31 27 22	479 ± 5	17.82	-11.35	NGC 2903	12.64

Table 1. (Contd.)

Group		Galaxy name	R.A. Dec	V_{LG} ,	m_B ,	M_B ,	MD	II
(1)	(2)	(3)	J2000	km/s	mag	mag	(8)	(9)
	B	UGC 5272	09 50 22.4 +31 29 16	453 ± 4	14.46	-14.59		
J0959+41	A	KUG 0956+420	09 59 30.0 +41 46 01	1704 ± 36	16.43	-15.47	NGC 2964	99.46
	B	KUG 0956+419	09 59 45.0 +41 40 37	1664 ± 3 [†]	16.61	-15.23		
J1016+37	A	UGC 5540	10 16 21.9 +37 46 47	1138 ± 4	14.60	-16.42	NGC 3245	66.28
	B	KUG 1013+381	10 16 24.5 +37 54 46	1150 ± 3	15.97	-15.07		
J1040-09	A	6dF J1039304-094609	10 39 30.4 -09 46 09	2177 ± 74	16.68	-15.85	NGC 3375	7.86
	B	6dF J1040118-095641	10 40 11.8 -09 56 40	2218 ± 74	16.48	-16.08		
J1052+00	A	MGC 0013223	10 52 40.6 -00 01 17	1569 ± 75	17.59	-14.26	UGC 5922	8.11
	B	CGCG 010-041	10 52 48.6 +00 02 04	1607 ± 5	15.62	-16.28		
J1053+02	A	LSBC L1-137A	10 53 03.1 +02 29 37	860 ± 5	17.59	-12.93	NGC 3379	5.35
	B	LSBC L1-137	10 53 18.6 +02 37 34	851 ± 10	15.80	-14.69		
J1101+30	A	BTS 028	11 01 32.4 +30 35 16	1708 ± 75	17.56	-14.38	NGC 3430	6.38
	B	BTS 029	11 01 38.9 +30 36 29	1626 ± 5	18.32	-13.52		
J1110+40	A	KUG 1107+403	11 10 25.2 +40 03 11	2943 ± 30	16.11	-16.98	NGC 3665	85.47
	B	SDSS J111026.28+400117.4	11 10 26.3 +40 01 17	\pm	19.06			
J1113+53	A	UGC 06251	11 13 26.1 +53 35 42	999 ± 5	16.33	-14.42	NGC 3992	2.14
	B	SDSS J111343.60+533848.3	11 13 43.6 +53 38 48	985 ± 5	18.04	-12.68		
J1131-35	A	6dF J1131390-352255	11 31 38.9 -35 22 56	2396 ± 48	16.52	-16.36	NGC 3742	3.50
	B	PGC 649656	11 31 39.6 -35 22 42	\pm	17.35			
J1134+48	A	SDSS J113342.71+482004.9	11 33 42.7 +48 20 05	3094 ± 20	17.69	-15.53	NGC 3811	5.94
	B	SDSS J113403.75+482834.4	11 34 03.9 +48 28 37	3107 ± 29	18.15	-15.09		
J1141+32	A	KUG 1138+327	11 41 07.4 +32 25 37	1704 ± 70	15.86	-16.08	IC 2957	5.64
	B	MRK 0746	11 41 29.9 +32 20 59	1684 ± 50	15.68	-16.24		
	C	SDSS J114136.70+321651.5	11 41 36.7 +32 16 52	1737 ± 2	17.00	-14.98		
J1146+58	A	SBS 1143+588	11 45 58.7 +58 32 07	1519 ± 37	15.75	-15.89	NGC 4036	2.00
	B	SDSS J114603.39+583621.8	11 46 03.4 +58 36 22	1518 ± 42	17.81	-13.83		
J1150-00	A	UM 456A	11 50 34.0 -00 32 16	1645 ± 16	17.07	-14.81	NGC 4472	10.39
	B	UM 456	11 50 36.2 -00 34 02	1574 ± 5	16.43	-15.35		

Table 1. (Contd.)

Group		Galaxy name	R.A. Dec	V_{LG} , km/s	m_B , mag	M_B , mag	MD	II
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
J1152−02	A	UM 461	11 51 33.4 −02 22 22	866 ± 9	14.71	−15.74	NGC 4472	6.02
	B	UGC 6850	11 52 37.4 −02 28 10	860 ± 6	14.72	−15.72		
J1154−03	A	SDSS J115348.29−031306.5	11 53 48.3 −03 13 06	1243 ± 12	18.00	−13.25	NGC 4030	2.30
	B	CGCG 012-113	11 54 07.6 −03 40 56	1223 ± 27	16.02	−15.20		
	C	SDSS J115503.67−033012.4	11 55 03.7 −03 30 12	1216 ± 69	18.02	−13.20		
J1157+02	A	SDSS J115725.14+021115.9	11 57 25.1 +02 11 16	839 ± 5	17.95	−12.45	NGC 4472	2.43
	B	SDSS J115735.27+021004.0	11 57 35.3 +02 10 04	796 ± 32	16.48	−13.81		
J1158+31	A	KDG 083	11 56 14.5 +31 18 16	617 ± 5	16.65	−13.06	NGC 4278	2.70
	B	KUG 1157+315	12 00 16.2 +31 13 30	593 ± 28	15.25	−14.36		
J1216+52	A	CGCG 269-049	12 15 46.8 +52 23 17	245 ± 15	15.27	−12.47	NGC 3031	5.51
	B	UGC 07298	12 16 30.1 +52 13 39	254 ± 5	16.64	−11.15		
J1221+38	A	KUG 1218+387	12 20 54.9 +38 25 49	623 ± 46	15.57	−14.16	NGC 4490	1.95
	B	KDG 105	12 21 43.0 +37 59 14	582 ± 5	17.57	−11.98		
J1224+28	A	[KK98] 138	12 21 58.4 +28 14 34	417 ± 8	18.88	−10.00	NGC 4278	2.28
	B	[KK98] 144	12 25 29.1 +28 28 57	453 ± 2	18.18	−10.87		
J1225+61	A	MCG +10-18-044	12 24 53.8 +61 03 49	833 ± 5	15.85	−14.50	NGC 3992	9.87
	B	SBS 1222+614	12 25 05.4 +61 09 11	832 ± 5	14.86	−15.49		
J1226−01	A	UGC 7531	12 26 11.8 −01 18 17	1858 ± 12	15.27	−16.86	NGC 4527	5.13
	B	UM 501	12 26 22.7 −01 15 12	1861 ± 14	16.41	−15.72		
J1228+22	A	UGC 7584	12 28 02.8 +22 35 16	545 ± 4	16.20	−13.25	NGC 4278	3.19
	B	KKH 80	12 28 05.0 +22 17 27	543 ± 5	17.00	−12.44		
	C	NGC 4455	12 28 44.1 +22 49 14	581 ± 5	13.05	−16.55		
J1244+62	A	MCG +11-16-003	12 43 59.9 +62 19 60	2739 ± 77	16.46	−16.48	NGC 4521	7.41
	B	MCG +11-16-005	12 44 12.0 +62 14 51	2750 ± 9	16.10	−16.85		
	C	SDSS J124411.92+621021.5	12 44 12.1 +62 10 19	2681 ± 12	18.00	−14.88		
	D	SDSS J124418.07+621007.7	12 44 18.0 +62 10 07	\pm	18.32			
	E	SDSS J124423.23+620305.5	12 44 23.2 +62 03 06	2660 ± 72	17.86	−15.01		
J1301−01	A	CGCG 1258.5−0142S	13 01 00.7 −01 58 34	1302 ± 5	17.04	−14.31	NGC 4699	3.11

Table 1. (Contd.)

Group		Galaxy name	R.A. Dec J2000	V_{LG} , km/s	m_B , mag	M_B , mag	MD	II
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	B	UGC 8127	13 01 03.7 −01 57 12	1297 ± 33	15.67	−15.67		
J1303−17	A	UGCA 319	13 02 14.4 −17 14 15	548 ± 8	15.08	−14.65	NGC 5068	10.32
	B	UGCA 320	13 03 16.7 −17 25 23	546 ± 5	13.40	−16.31		
J1304−02	A	LCRS B130157.2−024313	13 04 31.8 −02 59 17	1148 ± 34	16.27	−14.82	NGC 4699	2.26
	B	HIPASS J1304−02	13 04 46.6 −02 52 16	1122 ± 9	16.81	−14.23		
J1310+34	A	UGC 8246	13 10 04.5 +34 10 51	833 ± 5	14.55	−15.78	NGC 5005	1.38
	B	SDSS J131029.12+341411.5	13 10 29.2 +34 14 13	873 ± 75	18.92	−11.51		
J1315+47	A	DDO 169 NW	13 15 18.4 +47 32 00	328 ± 75			NGC 4736	1.57
	B	UGC 08331	13 15 30.3 +47 29 56	344 ± 6	14.60	−13.82		
J1337+32	A	SDSS J133605.53+320823.2	13 36 05.6 +32 08 21	\pm	17.94		NGC 5353	36.57
	B	UGC 8602	13 36 45.5 +32 05 28	3062 ± 5	17.54	−15.63		
	C	UGC 8605	13 36 54.3 +32 05 44	3035 ± 5	17.57	−15.58		
	D	SDSS J133657.55+320208.4	13 36 57.5 +32 02 08	3106 ± 29	16.90	−16.30		
	E	UGC 8608	13 37 00.9 +31 46 00	3033 ± 3	16.04	−17.13		
	F	SDSS J133704.69+315337.9	13 37 04.7 +31 53 37	\pm	18.23			
J1355+04	A	KKH 86	13 54 33.5 +04 14 35	209 ± 5	16.88	−9.36	LG	9.56
	B	SDSS J135429.53+041237.1	13 54 29.5 +04 12 37	\pm				
J1404+61	A	UGC 08982	14 03 00.0 +61 45 04	1868 ± 31	15.48	−16.62	NGC 5322	1.02
	B	SDSS J140524.63+613401.3	14 05 24.6 +61 34 01	1883 ± 5	16.81	−15.31		
J1423+21	A	SDSS J142332.69+213112.1	14 23 32.8 +21 31 18	\pm	19.86		NGC 4472	50.1
	B	SDSS J142337.04+213128.2	14 23 37.0 +21 31 28	2068 ± 21	19.12	−13.31		
J1428+21	A	UGC 9274	14 28 02.8 +21 18 14	1117 ± 73	14.35	−16.69	NGC 4472	32.34
	B	UGC 9282	14 28 41.6 +21 20 22	1155 ± 5	16.17	−14.96		
J1437+59	A	SDSS J143659.37+590535.1	14 36 59.3 +59 05 36	\pm	18.34		NGC 5777	6.70
	B	SDSS J143703.11+590606.3	14 37 02.0 +59 05 55	2402 ± 10	18.34	−14.28		
J1450+36	A	SDSS J144948.75+362347.3	14 49 48.8 +36 23 47	1979 ± 5	16.96	−15.26	UGC 9519	69.09
	B	SDSS J144951.10+362501.5	14 49 51.1 +36 25 02	1978 ± 32	16.69	−15.53		
J1648+21	A	SDSS J164711.10+210527.0	16 47 11.1 +21 05 27	2727 ± 2 †	16.76	−16.32	NGC 6181	30.25

Table 1. (Contd.)

Group		Galaxy name	R.A. J2000	Dec	V_{LG} , km/s	m_B , mag	M_B , mag	MD	II
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	
J1657+38	B	UGC 10549	16 47 26.5	+21 07 32	2719 ± 9	16.23	−16.87	NGC 6339	370.21
	C	SDSS J164802.08+213330.5	16 48 02.1	+21 33 30	2753 ± 12 [†]	17.48	−15.71		
	A	UGC 10625	16 57 23.1	+38 40 19	2252 ± 6	16.88	−15.63		
	B	SHOC 553	16 57 30.0	+38 41 23	2255 ± 5	16.90	−15.62		
J2227−09	A	6dF J2227305−093959	22 27 30.5	−09 39 59	1866 ± 74	15.64	−16.62	NGC 253	313.57
	B	MCG −02-57-007	22 27 41.5	−09 43 37	1786 ± 43	15.81	−16.35		

While compiling our list of dwarf galaxy groups we found that some of the SDSS redshifts were determined using the cross-correlation method. Though the emission lines, sometimes very bright, are present in the spectrum, for some reason no velocity estimates were made based on these lines (the SDSS provides no table of emission-based redshifts). As a result, the accuracy of the line-of-sight velocity determinations for such objects proved to be substantially lower. In some other cases, the redshifts were determined incorrectly. Using the SDSS spectra we measured the heliocentric velocities from the emission lines of several galaxies:

J0817+24B = KUG 0814+251,

J0959+41B = KUG 0956+419,

J1648+21A = SDSS J164711.10+210527.0, and

J1648+21C = SDSS J164802.08+213330.5.

The velocity values of these galaxies are marked by the [†] sign.

J0714+44. The distances to the galaxies of this very isolated group were deter-

mined by Makarova and Karachentsev [18] by the brightest blue stars. The two galaxies are located at the same distance within the measurement errors, 7.2 Mpc and 7.9 Mpc for UGC 3698 and NGC 2337, respectively, and 8.6 Mpc for UGC 3817 with a typical error of around $(1 \div 1.5)$ Mpc. This also provides yet another independent evidence of the physical boundedness of galaxies in the system. Note that NGC 2337 and UGC 3698 are located at a projected distance of 25 kpc, whereas UGC 3817 resides 2^o3 from them or at a projected distance of 0.3 Mpc. Such separations are typical for associations of dwarf galaxies.

J0742+16. This pair, together with UGC 3755 and UGC 4115, forms the 14+19 association from Tully et al. [11]. All these galaxies have precise distance measurements based on the tip of the red giant branch method. Despite their small line-of-sight velocities, they are located at the distances of 8.05 (UGC 3974) and 8.02 (CGCG 087-033) Mpc. A high peculiar ve-

locity of around -420 km/s is due to the “local velocity anomaly” [19].

J0911+42 structurally resembles the nearby bright irregular galaxy NGC 4449 with ongoing star formation, which is merging the dwarf low surface brightness spheroidal galaxy d1228+4358 [20, 21] in what is believed to be a case of a dwarf galaxy merger in [22]. Note that the J0911+42 pair is much more isolated and its primary galaxy is about 3 mag fainter than NGC 4449 (note that NGC 4449 was not included in our list due to its luminosity $M_K = -20.4$).

J1110+40 B is a low surface brightness dwarf galaxy with an unknown line-of-sight velocity, which is located at a distance of $1'.9$ (at a projected distance of about 23 kpc) south of KUG 1107+403 and is a possible companion of this galaxy.

J1131-35 is a close pair of galaxies with a separation of $16''$ corresponding to a projected mutual distance of 2.6 kpc from each other. Velocity is known only for one of these galaxies.

J1150-00. At an angular distance of $3'$ northwest of the UM 456 and UM 456A pair the UM 455 galaxy is located, but it has a substantially higher line-of-sight velocity ($V_{LG} = 3680$ km/s).

J1244+62 is a chain of five dwarf galaxies extending over 180 kpc. The system appears to be in the process of formation.

J1310+34 The disk of the UGC 8246 galaxy is warped, possibly, due to the interaction with the second component of the pair.

J1337+32 is one of the most populated groups in our list. It contains six members. One of the galaxies, J1337+32 F was included into the group based on the morphological criteria. According to the SDSS, the velocity of this galaxy, SDSS J133704.69+315337.9 is equal to $V_h = 41791$ km/s. However, the quality of the spectrum does not allow to reliably estimate its redshift. The morphology of this low surface brightness galaxy suggests that the velocity estimate in question is erroneous.

J1355+04 B was discovered by I. Karachentsev (private communication) at an angular distance of $2'.2$ (corresponding to a projected distance of 1.6 kpc) from the nearby isolated dwarf galaxy KKH 98. J1355+04 B is 2–2.5 mag fainter than KKH 98, which, in the case if the two galaxies are located at the same distance, makes it comparable in brightness to the ultra-faint dwarfs in our Galaxy.

J1423+21 is a pair of dwarf galaxies with an angular separation of $1'$ corresponding to a projected separation of 8 kpc. The line-of-sight velocity $V_h = 2049$ of the ADBS 142335+2131 object was measured in the process of the Arecibo Dual-Beam Survey [23] and may refer to both objects.

J1437+59 is a close pair of dwarf galaxies with an angular separation of $43''$ corresponding to a projected separation of 7 kpc. Velocity is known only for one object.

J1648+21. The complex structure of the J1648+21 A galaxy is either due to a burst of

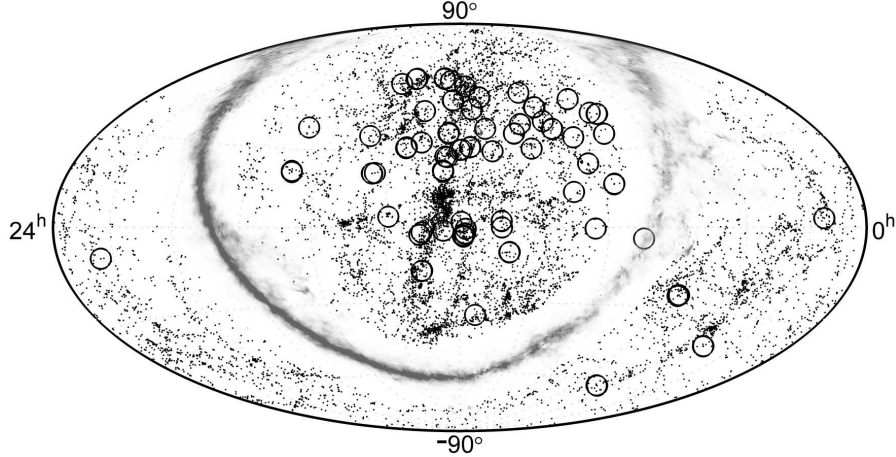


Figure 2. The distribution of groups of dwarf galaxies on the sky. The dots indicate the positions of nearby ($V_{LG} < 3500$ km/s) galaxies. Groups of galaxies are marked by circles. The Milky Way is shown by gray clouds.

star formation or to the tidal influence of the UGC 10549 galaxy despite their rather large separation (the projected separation is equal to 45 kpc). The third member of the group, J1648+21C, is located $29'$ north of the two brighter galaxies at a projected distance of 300 kpc.

4. MAIN PROPERTIES OF DWARF GALAXY GROUPS

Figure 2 shows the sky distribution of groups of dwarf galaxies. The overwhelming majority of the systems are concentrated in one third of the sky covered by the SDSS survey. This fact reflects strong observational selection, inherent to our sample. Unfortunately, the selection effects are practically impossible to account for. The factors affecting the completeness of our data include both the coverage of modern sky surveys and selection of candidates for the further

spectroscopic analysis. Low-luminosity and low-surface brightness galaxies are usually unobservable. One may expect the real number of groups consisting of dwarf galaxies alone to be appreciably greater than the 57 groups already identified (about 5% of the total number of groups) on the scale of the Local Supercluster. Despite the selection effects, it can be pointed out that multiple dwarf systems avoid the known concentrations of luminous matter, and their distribution is substantially more uniform. Note that dwarf galaxies evade the $15^h < \alpha < 18^h$ region. This is especially evident from a comparison with a similar region located symmetrically with respect to the plane of the Local Supercluster. This fact appears to be due to an extreme deficit of dwarf galaxies in the Local Void [24].

Figure 3 shows the luminosity function of the objects of our sample compared to associations of dwarf galaxies. The groups of dwarf galaxies (shown in black) occupy the same interval of ab-

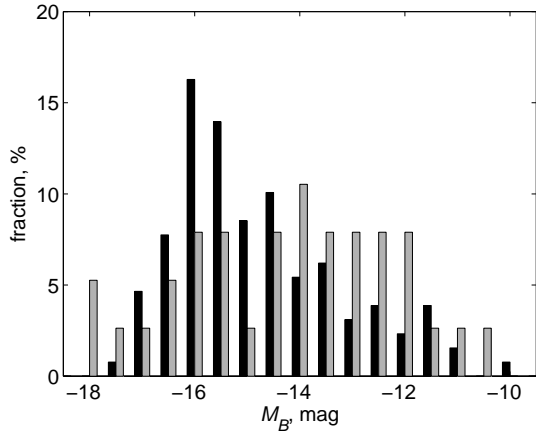


Figure 3. The luminosity function of galaxies of our sample compared to the associations of Tully et al. [11].

solute magnitudes as associations (shown in light gray). The completeness of data of the Catalog of Neighboring Galaxies (CNG) [25] approaches 100% on a 2 Mpc scale down to an absolute magnitude of $M_B = -10$. It is evident that the sharp decrease of the number of galaxies in our list with luminosities below $M_B = -15^m5$ is due to the observational selection. Let us assume that the luminosity function of galaxies in groups of dwarfs is proportional to the distribution obtained for galaxies located out to 3 Mpc, and take into account the fact that the SDSS survey, which is the main contributor to our data, covers about one third of the sky. We can hence make a crude estimate of the total number of systems of dwarf galaxies on the scale of the Local Supercluster. There should be five to six times more groups of dwarf galaxies than we have actually found so far.

It is evident from Fig. 4 that the groups of dwarf galaxies span over a wide range of values

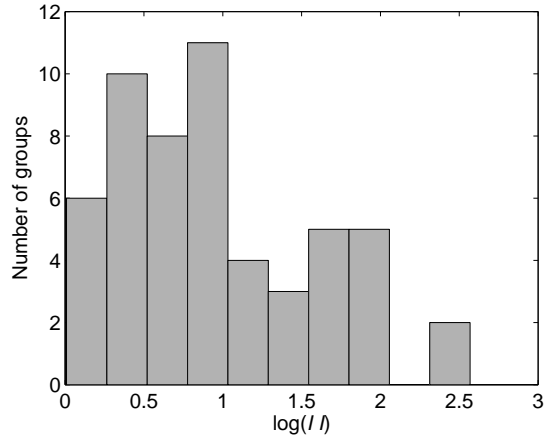


Figure 4. The distribution of isolation indices of the dwarf galaxy groups.

of the isolation index (II). This index is equal to the factor by which the masses of all galaxies should be multiplied for the given group or galaxy to be gravitationally bound with other systems. $II \sim 1$ means that the system in question is located near the zone of gravitational influence or, in other words, is near the zero-velocity surface of its more massive companion. Large II values correspond to the regions of low matter density in the Universe, which are located far from massive gravitating centers.

Figure 5 shows the distribution of groups by the size and internal motions within the system. The black symbols indicate the groups of dwarfs with different numbers of members: the dots, triangles, and asterisks show pairs, triplets, and more populated groups, respectively. The dispersion of the line-of-sight velocities (σ_V) in groups of dwarfs reaches 60 km/s with a median value of 11 km/s, and the projected sizes of groups do not exceed 200 kpc with the median value amounting

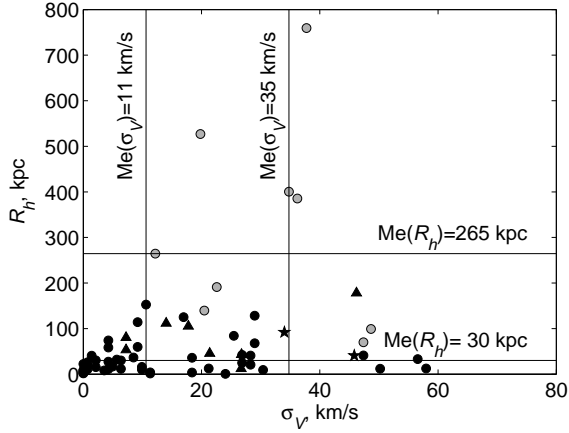


Figure 5. The dependence of the size of groups from the internal velocity dispersion. The black symbols show the groups of our sample (the circles, triangles, and asterisks correspond to pairs, triplets, and more populated systems, respectively). The gray circles show the associations of Tully et al. [11].

to 30 kpc.

Table 2 summarizes the main parameters of groups of galaxies in the Local Supercluster, the

Table 2. A comparison of the main parameters of normal groups of the Local Supercluster (NGLC), groups of dwarf galaxies (GD), and associations of dwarf galaxies (AD)

	n	σ_V , km/s	R_h , kpc	M_p , $10^{10} M_\odot$	L , $10^9 L_\odot$	M/L , M_\odot/L_\odot
NGLC	1082	42	160	61	42	21
$n = 2$	516	24	121	14	17	11
$n = 3$	171	41	156	46	40	15
$n \geq 4$	395	74	204	330	120	31
AD	7	35	265	38	1.0	380
GD	57	11	30	0.96	0.35	45
$n = 2$	47	9	22	0.29	0.29	26
$n = 3$	8	20	67	4.6	0.69	83
$n \geq 4$	2	40	66	26	2.0	129

associations and groups of dwarf galaxies. This table gives the median values of velocity dispersion σ_V , the harmonic radius of systems R_h , projected mass M_p , luminosity L , and mass-to-luminosity ratio M/L . For the groups in the Local Supercluster and the groups of dwarfs the parameters are given both for the entire sample of these groups and for particular configurations: pairs ($n = 2$), triplets ($n = 3$), and other groups ($n \geq 4$). A comparison of the data shows that the groups of dwarfs are the most compact formations. The sizes of groups from our sample are about one order of magnitude smaller than those of normal groups and associations. Velocity dispersions do not differ so drastically, however, groups of dwarf galaxies again possess the lowest values, which are a factor of seven and three smaller than those of normal groups, and associations, respectively. Nevertheless, the dwarf systems are intermediate between groups of galaxies and associations in terms of the mass-to-luminosity ratio. The list of dwarf groups consists of 47 pairs, 8 triplets, and only two more populated groups. This statistics is too small to analyze the differences between the systems with different numbers of neighbors. Note, however, that the physical parameters systematically vary with the growing number of group members. The triplets of dwarf galaxies prove to be systematically wider, more massive, and to contain more luminous matter compared to similar pairs of dwarfs. The mass-to-luminosity ratio also increases with the number of members in

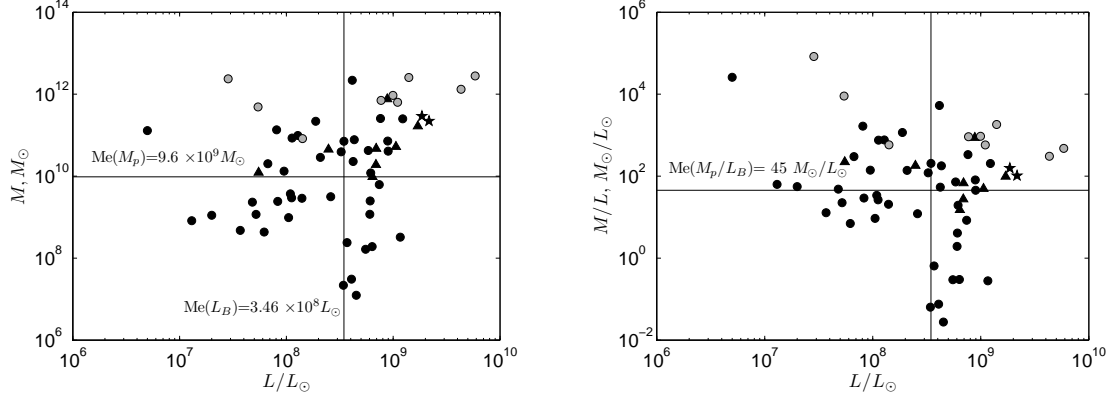


Figure 6. The left-hand panel demonstrates the mass-to-luminosity relation for groups and associations of dwarf galaxies; the right-hand panel shows the “mass-to-luminosity ratio–luminosity” relation. The black symbols mark the groups of our sample (the dots, triangles, and asterisks show the pairs, triplets, and groups with $n \geq 4$ members, respectively). The gray circles show the associations of dwarf galaxies.

the group.

The gray circles in Fig. 5 show the distribution of associations of dwarf galaxies [11]. The associations were discovered in the Local Volume exclusively via analyzing the spatial distribution of galaxies based on high-precision distance measurements. As Tully et al. [11] pointed out, almost all dwarf galaxies in the Local Volume, except for KKR 25, are the members of groups and associations. The associations are rather sparse structures. A typical size of an association ($R_h = 265$ kpc) is almost equal to the typical size of groups of normal galaxies, whereas the total luminosity of associations is two orders of magnitude lower than that of groups in the Local Supercluster. Although the groups and associations differ by a factor of three in terms of velocity dispersions, they differ substantially, by a factor of nine, in terms of the characteristic size. This fact is a manifestation of the fundamental difference

between the sample construction processes. The associations were identified based on the spatial correlation of objects, whereas the groups of galaxies were identified based on the kinematical data only, selecting candidates for physically bound groups of galaxies. The requirement that the groups should be gravitationally bound, combined with the luminosity-based mass estimates, necessarily implies small projected distances and small velocity differences between the companions of dwarf systems.

The median B -band luminosity of groups of dwarf galaxies is $3.5 \times 10^8 L_\odot$, and the median projected mass value is $9.6 \times 10^9 M_\odot$. This implies a mass-to-luminosity ratio of $45 M_\odot/L_\odot$. Note that individual mass estimates for groups of dwarf galaxies are highly uncertain because of the small multiplicity of the systems (which are mostly binary galaxies). We can therefore deal with ensemble-averaged quantities. Figure 6

shows the dependences of the mass and the mass-to-luminosity ratio on the total luminosity. It is evident from the figure that the associations are, on the average, more massive than the groups of dwarfs. It should, however, be noted that despite the use of different identification algorithms and substantial difference in their sizes and velocity dispersions, groups and associations of dwarf galaxies form a continuous sequence on the “mass–luminosity” diagrams. This fact is a manifestation of the genetic relationship of these systems.

5. CONCLUSIONS

Over the past decade modern mass surveys have substantially increased the number of galaxies with known velocities in the Local Supercluster. We constructed a catalog of systems consisting of dwarf galaxies only based on the catalog of groups in the Local Supercluster [8]. Our catalog contains groups where the brightest galaxy has a K -band luminosity lower than $M_K = -19$. Such systems make up about 5% of all groups in the Local Supercluster. However, with selection effects taken into account, the total number of multiple dwarf systems should be at least a factor of five to six greater. The groups of dwarf galaxies are characterized by the mean size of 30 kpc and a mean velocity dispersion of 11 km/s. Both these values are much smaller than the corresponding parameters for typical groups in the Local Supercluster (204 kpc and 74 km/s, respec-

tively). Our sample of dwarf galaxy groups forms a continuous sequence in the mass and luminosity distribution diagrams along with associations identified by Tully et al. [11] based on an analysis of the three-dimensional distribution of nearby dwarf galaxies. The groups and associations of dwarfs have similar luminosities, however, the groups are by one order of magnitude more compact. The median mass-to-luminosity ratio for the groups of dwarfs is equal to $45 M_\odot/L_\odot$, which is indicative of a greater amount of dark matter, as compared to normal groups.

The systems of dwarf galaxies may contain substantial amounts of dark matter. Such “dark” aggregates may be quite numerous. They are difficult to reveal and study and can therefore “hide” a substantial fraction of dark matter, which remains undiscovered in the studies of groups of galaxies. This may partially solve the problem of “missing” mass—the discrepancy between the estimates of the average density of the Universe based on the analyses of cosmic background radiation, and the estimates ensuing from the analysis of groups of galaxies in the Local Supercluster [8].

Note that the issues of the formation and evolution of the systems of dwarf galaxies remain highly unexplored. This is due to the difficulties one has to face in the process of observations and interpretation, and the problems of the theoretical approach. When we study groups consisting of dwarf galaxies only, we have to address a large number of problems: the low surface brightness

and low luminosity make such systems hardly accessible for observations, whereas their small masses impose very severe constraints in cosmological computations. Our list of dwarf galaxy groups formed the basis for the spectroscopic survey, currently conducted at the 6-m telescope of the Special Astrophysical Observatory of the Russian Academy of Sciences since 2008. The main goal of the survey is to study the chemical composition of dwarf galaxies in groups and determine the evolutionary status of such systems.

ACKNOWLEDGMENTS

This work was supported by the Russian Foundation for Basic Research (grant nos. 11-02-00639 and 11-02-90449) and the Ministry of Education and Science of Russian Federation (state contracts no. 14.740.11.0901, 16.552.11.7028, 16.518.11.7073). The research has made use of the HyperLEDA database (<http://leda.univ-lyon1.fr>).

-
1. M. Colless, G. Dalton, S. Maddox, et al., *Monthly Notices Roy. Astronom. Soc.* **328**, 1039 (2001).
 2. M. A. Zwaan, L. Staveley-Smith, B. S. Koribalski, et al., *Astronom. J.* **125**, 2842 (2003).
 3. D. H. Jones, W. Saunders, M. Colless, et al., *Monthly Notices Roy. Astronom. Soc.* **355**, 747 (2004).
 4. R. Giovanelli, M. P. Haynes, B. R. Kent, et al., *Astronom. J.* **130**, 2598 (2005).
 5. K. N. Abazajian, J. K. Adelman-McCarthy, M. A. Agüeros, et al., *Astrophys. J. Suppl.* **182**, 543 (2009).
 6. I. D. Karachentsev and D. I. Makarov, *Astrophysical Bulletin* **63**, 299 (2008).
 7. D. I. Makarov and I. D. Karachentsev, *Astrophysical Bulletin* **64**, 24 (2009).
 8. D. Makarov and I. Karachentsev, *Monthly Notices Roy. Astronom. Soc.* **412**, 2498 (2011).
 9. J. N. Chengalur, S. A. Pustilnik, J.-M. Martin, et al., *Monthly Notices Roy. Astronom. Soc.* **371**, 1849 (2006).
 10. Ekta, J. N. Chengalur, and S. A. Pustilnik, *Monthly Notices Roy. Astronom. Soc.* **372**, 853 (2006).
 11. R. B. Tully, L. Rizzi, A. E. Dolphin, et al., *Astronom. J.* **132**, 729 (2006).
 12. T. H. Jarrett, T. Chester, R. Cutri, et al., *Astronom. J.* **119**, 2498 (2000).
 13. T. H. Jarrett, T. Chester, R. Cutri, et al., *Astronom. J.* **125**, 525 (2003).
 14. K. Davidson, T. D. Kinman, and S. D. Friedman, *Astronom. J.* **97**, 1591 (1989).
 15. I. D. Karachentsev and D. A. Makarov, *Astronom. J.* **111**, 794 (1996).
 16. S. Jester, D. P. Schneider, G. T. Richards, et al., *Astronom. J.* **130**, 873 (2005).
 17. G. Paturel, C. Petit, P. Prugniel, et al., *Astronom. and Astrophys.* **412**, 45 (2003).
 18. L. N. Makarova and I. D. Karachentsev, *Astronom. and Astrophys. Suppl. Ser.* **133**, 181 (1998).
 19. R. B. Tully, E. J. Shaya, and M. J. Pierce, *Astrophys. J. Suppl.* **80**, 479 (1992).
 20. I. D. Karachentsev, V. E. Karachentseva, and W. K. Huchtmeier, *Astron. Lett.* **33**, 512 (2007).

- 21. W. K. Huchtmeier, I. D. Karachentsev, and V. E. Karachentseva, *Astronom. and Astrophys.* **506**, 677 (2009).
- 22. D. Martinez-Delgado, A. J. Romanowsky, R. J. GaBany, et al., *ArXiv:1112.2154* (2011).
- 23. J. L. Rosenberg and S. E. Schneider, *Astrophys. J. Suppl.* **130**, 177 (2000).
- 24. W. K. Huchtmeier, I. D. Karachentsev, and V. E. Karachentseva, *Astronom. and Astrophys. Suppl. Ser.* **147**, 187 (2000).
- 25. I. D. Karachentsev, V. E. Karachentseva, W. K. Huchtmeier, et al., *Astronom. J.* **127**, 2031 (2004).